Buffer Zone
Sampling and Analysis Plan
FY04 Addendum #BZ-04-01
IHSS Group 900-11, IHSS 155 Inner Lip Area
and Associated Remediation Approach
Revision 1

February 2004

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Approval received from the U S Environmental Protection Agency
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ACRONYMS

AL	action level
AOC	area of concern
BZ	Buffer Zone
BZSAP	Buffer Zone Sampling and Analysis Plan
DOE	U S Department of Energy
EPA	U S Environmental Protection Agency
FY	Fiscal Year
HRR	Historical Release Report
IHSS	Individual Hazardous Substance Site
IM/IRA	Interim Measure/Interim Remedial Action
K-H	Kaiser-Hill Company, LLC
OU	Operable Unit
PAC	Potential Area of Concern
pCi/g	picocuries per gram
PCOC	potential contaminant of concern
RCRA	Resource Conservation and Recovery Act
RFCA	Rocky Flats Cleanup Agreement
RFI/RI	RCRA Facility Investigation/Remedial Investigation
SAP	Sampling and Analysis Plan

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1.0 INTRODUCTION

This Buffer Zone (BZ) Sampling and Analysis Plan (SAP) (BZSAP) (DOE 2002) Addendum #BZ-04-01 includes Individual Hazardous Substance Site (IHSS) Group-specific information, sampling locations, and potential contaminants of concern (PCOCs) for IHSS 155 (Inner Lip Area) proposed for characterization during Fiscal Year (FY) 04 This BZSAP Addendum is a supplement to the BZSAP (DOE 2002)

The purpose of this SAP is to describe the pre-screen sampling, the confirmation sampling and remedial activities associated with the sampling

1.1 IHSS GROUP 900-11

Respectively, IHSS Group 900-11 consists of the following IHSS Sites and Potential Area of Concern (PAC)

- 112 – 903 Pad
- 140 – Hazardous Disposal Area
- 155 – 903 Lip Area
- SE-1602 – East Firing Range

IHSS 112, the 903 Pad, is currently undergoing rememdation and will be addressed via a separate closeout report IHSS Site 140, the Hazardous Disposal Area, was proposed for No Further Action (NFA) in 1998 (DOE 1992-2002) PAC SE-1602, the East Firing Range, will be addressed via a separate SAP Addendum IHSS Site 155, the 903 Lip Area, will be addressed via two documents This BZSAP Addendum (BZ-04-01) addresses the 903 Inner Lip Area, while the 900-11 Interim Measure/Interim Remedial Action (IM/IRA) will address the 903 Outer Lip Area

The 903 Inner Lip Area (IHSS 155) is primarily an area east and south of the 903 Pad where wind and rain spread plutonium-contaminated soil from the 903 Pad Area The locations of the IHSSs and PACs in the vicinity are shown on Figure 1

Several limited excavations have removed some of the contaminated soil from the 903 Inner Lip Area However, results from the Operable Unit (OU) 2 Phase II Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) sampling and analysis and the Site Characterization Report for the 903 Drum Storage Area, 903 Lip Area, and the Americium Zone (DOE 1995) confirm that radionuclide-contaminated soil remains The contamination is primarily attributed to wind dispersion form the 903 Pad and stormwater-related surface soil erosion

The PCOCs for IHSS 155 are listed in Table 1 Proposed new sampling locations are the starting point for IHSS Group characterization After characterization starts, the number and type of samples may change based on sampling results Changes to sampling specifications will be considered in consultation with the regulatory agencies

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Table 1
IHSS Group 900-11, IHSS 155

IHSS Group	IHSS/PAC/UBC Site	PCOCs	Media	Data Source	Sampling Method
900-11	IHSS 155	Radionuclides	Surface soil	HRRs (DOE 1992-2002) Process knowledge (IASAP [DOE 2001])	Composited grab

2.0 EXISTING CHARACTERIZATION INFORMATION

Existing information and data for this IHSS are available in Appendix C of the BZSAP (DOE 2002) and the Historical Release Reports (HRRs) (DOE 1992-2002) Existing gamma spectroscopy data associated with the IHSS 155 plutonium-239/240 activities are presented on Figure 2 These data represent the starting point for determining further characterization sampling Pre-screen samples are currently being collected and analyzed

3.0 GRID CELL SAMPLING

A grid cell approach will be utilized around the perimeter of the 903 Pad and the area immediately east of the 903 Pad due to the following

- Historical information indicates fill material may be been placed and soil disturbance may have occurred, therefore, the potential contamination may not follow the pattern of typical erosion deposition,
- Limited and variable characterization data, and
- Proximity to the 903 Pad

Grid sizes for this area of the 903 Inner Lip area are based on the geostatistical methods presented in the BZSAP (DOE 2002) The grid size for the 903 Inner Lip area will be 42-foot squares The grid locations and orientation are located on Figure 3 Not all of the 903 Inner Lip area is included in the grid cell sampling approach The portion south of grid cells AA12 through J12 and K11 through U11 of the 903 Inner Lip area is addressed using a kriging technique, described in a later section, that better accounts for the wind, rain, and erosional deposition that occurred in this area

Note that the 903 Pad is currently undergoing remediation and confirmation sampling, therefore, no additional samples will be collected in this area

The combination of previous characterization data and "pre-screen" characterization sampling effort will determine whether remediation activities are required within grid cell locations If previous characterization sample data collected within a grid cell show soil concentrations above their respective action levels (ALs), as described in the Rocky Flats Cleanup Agreement (RFCA) Attachment 5, 2003 Modification, those specific grid cells will be remediated If previous characterization sample data collected within a grid cell show soil concentrations below their respective ALs, those specific grid cells will be sampled using the "pre-screen" sample methodology described below Radiological soils samples will provide sufficient data to determine whether the contaminant concentration exceeds ALs On Figure 3, the boundary of the

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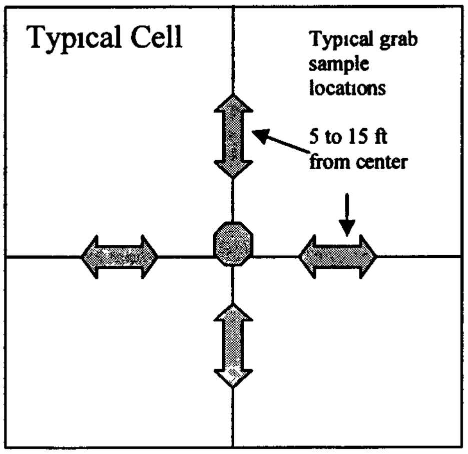
grid illustrates the potential area of remedial action associated with the pre-screen methodology The remaining portion south of grid cells AA12 through J12 and K11 through U11 will be addressed using the kriging technique

3.1 Pre-screen Methodology

If there are no previous sample characterization data within grid cells or the previous characterization sample data shows activity levels below AL, composite pre-screen samples will be collected prior to the remedial action to document contamination levels in each grid cell Where applicable, soil samples will be collected directly below the clean fill placed to support the 903 Pad remediation project Remediation decisions will be based on the results of this prescreen sample If radionuclide activities are below their respective ALs, as described in the RFCA Attachment 5, 2003 Modification, the consultative process will be invoked to develop a remedial approach for those specific grid cells If radionuclide activities are above their respective ALs, those specific grid cells will be remediated

Grid cells having existing characterization data indicating soil contamination that exceeds the AL at depths greater than 6 inches, will be excavated to the depths indicated in the Characterization Report for the 903 Drum Storage Area, 903 Lip Area, and the Americium Zone (K-H, June, 2000) Confirmation samples will be collected and analyzed to verify the grid cell has met the remedial objectives

Each composite sample collected for radiological characterization will consist of five soil aliquots (grab samples) collected from the grid cell as shown below One aliquot will be collected at the center point of the grid cell and the other four aliquots will be collected from 5 to 15 feet from the center point of the cell along the central axes of the cell The vertical and horizontal location of the composite sample will be assigned to the center of the cell as surveyed



Remediation for the grid cell areas will consist of removal of the upper 6 inches of native soil A composite confirmation sample will be collected from each grid cell after the 6 inches of soil are removed to determine whether the remedial action objectives have been met or additional excavation and confirmation sampling will be necessary If the composite confirmation analysis indicates the soil is below 50 pCi/g Pu, then the remedial action objectives have been met

3.2 Confirmation Samples

Confirmation samples will be collected from each grid cell following the removal of the upper 6 inches of soil to verify that the site has met the remedial objectives If radiological contamination is found above the action levels in the field screening gamma spectroscopy, additional soil will be removed from the grid cell and another confirmation sample will be collected

Once the field screening indicates that the soil is below the action level, the sample will be sent to the onsite laboratory for gamma spectroscopy Ten percent of the samples analyzed by gamma spectroscopy will be sent for alpha spectroscopy analysis (LIC ASP-A-003 or EAS-A-002)

Each composite confirmation sample collected for radiological characterization will consist of five soil aliquots (grab samples) collected from the bottom of the excavation in the same manner as the pre-screen sample One aliquot will be collected at the center point of the cell and the other four aliquots will be collected from 5 to 15 feet from the center point of the cell along the central axes of the cell The vertical and horizontal locations of the composite sample will be assigned to the center of the cell as surveyed

All five aliquots will be placed into a disposable bowl and thoroughly mixed A composite soil sample will be collected from the mixed soil and placed into a 500-cc plastic jar and analyzed by gamma spectroscopy Field duplicate samples for gamma spectroscopy will be collected at a minimum frequency of one per every 10 grid cells The field duplicate will be collected and analyzed just as the confirmation sample

EPA has generated one random grid cell in each north-south column of grid cells from which Kaiser-Hill will provide approximately 50 grams of soil from the composited soils for the confirmation sample from the final depth for that particular cell This sample will be known as the EPA split sample and will be taken from the following cells K7, L10, M4, N2, O7, P9, Q4 R11, S11, T3, U2, V6, W7 and X4 At EPA's earliest convenience, it will take custody of the split sample and store it in a lockbox in the T124E sample cooler until shipping it to its Montgomery, Alabama laboratory for analysis by alpha spectroscopy

4.0 DATA EVALUATION (KRIGING)

Kaiser Hill evaluated the southern portion of the 903 Inner Lip area containing extensive field HPGe characterization data to determine the limits of remediation The area is bordered by the grid cells to the north and the existing road to the south and east The western limits include the extent of the HPGe data, as shown on Figure 2

The evaluation used geostatistical methods that have been widely applied in environmental characterization (Myers 1997) Geostatistical approaches customize the analysis to account for many of the unique features of the contaminant distribution at a particular site The kriging process used in geostatistical studies uses optimal estimation (minimum error), which ensures a high quality to the model In addition, geostatistical techniques provide a measure of the confidence in the estimations Attachment A contains a detailed description of the kriging process

4.1 Kriging Results

The kriging resulted in the generation of a map (Figure 4) identifying the limits of remediation with a 90-percent level of confidence that all of the plutonium-239/240 contamination greater than 50 pCi/g is contained within the kriged boundary

4.2 Remediation Activities

The remediation area shown on Figure 4 will be remediated using standard excavation equipment including track hoes, loaders, etc Soil contaminated above 50 pCi/g Pu will be removed in 1 to 6-inch lifts depending on the estimated thickness of the contamination The excavated soil will be placed into intermodals for off site disposal Due to the wind blown deposition and the topography of the area, the contamination is expected to be thinner as distance from the 903 Pad increases

Excavation will be sequenced in a down-sloped direction to minimize the potential for recontaminating previously completed areas Confirmation sampling will be conducted on a daily basis for areas excavated that day If a confirmation sample result is greater than 50 pCi/g Pu (calculated), additional soil will be excavated from a 42-foot square area centered on the confirmation sample location Another sample will be collected and analyzed after the additional excavation is completed This process will continue until the confirmation sample result indicates that the contamination is below 50 pCi/g Pu (calculated) Once this process is completed the area will be regraded as necessary and degradable erosion mat will be installed

4.3 Confirmation Sampling

After excavation of soil greater than 50 pCi/g of plutonium-239/240 within the 3 8-acre remediation area of the Inner Lip as determined by the kriging, confirmation sampling will be conducted to demonstrate that the remediation objectives have been met The confirmation sampling will include the 96 individual grab samples on a 42-foot interval as shown on Figure 5 The 42-foot interval for confirmation sampling is based on the geostatistical methodologies described in Section 4 5 2 of the BZSAP (DOE 2002) A soil sample will be collected at each location from the upper three-inches of soil and analyzed by gamma spectroscopy Ten-percent of the samples will be sent off-site for alpha spectroscopy K-H will provide a split alpha sample of approximately 50 grams of soil for EPA Handling and storage will be similar to the description in Section 3 2

5.0 REFERENCES

Rockwell International, 1989, Interim Status Closure Plan Solid Waste Management Unit 15, Rocky Flats Plant, Golden, Colorado

DOE, 1992-2002, Historical Release Reports for the Rocky Flats Plant, Golden, Colorado

DOE, 1995 Final Phase II RFI/RI Report, 903 Pad, Mound, East Trenches Area, Operable Unit No 2, Rocky Flats Environmental Technology Site, Golden, Colorado

DOE, 2001, Industrial Area Sampling and Analysis Plan, Rocky Flats Environmental Technology Site, Golden, Colorado, June

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DOE, 2002 Fınal Buffer Zone Samplıng and Analysıs Plan, Rocky Flats Envıronmental Technology Sıte, Golden, Colorado, March

Myers, J C 1997 Geostatıstıcal Error Management Quantıfyıng Uncertaınty for Envıronmental Samplıng and Mappıng http //www gemdqos com New York Van Nostrand Reınhold

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Attachment A
Detailed Description of Kriging

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Geostatistical Analysis of the 903 Pad Lip Area at Rocky Flats

I. Introduction

Surface soils in the 903 Pad Lip Area (Lip Area) of the Rocky Flats Environmental Technology Site (RFETS) have been sampled extensively Sample results indicate that two types of areas exist (1) those where the activity of $^{239/240}Pu$ exceeds the threshold action level of 50 pCi/g ("dirty"), and, (2) those where the $^{239/240}Pu$ activity does not exceed 50 pCi/g ("clean") The activity in unsampled soils between clean and dirty locations must be assessed in order to determine the extents of excavation

Two basic options exist for assessing the remedial requirements for unsampled areas The first is to estimate the actual amount of activity in the soils using nearby sample data points The second is to calculate the probability that the soils exceed the 50 pCi/g threshold, i e the probability that they are dirty

The RFETS has selected and implemented the latter approach RFETS has applied a geostatistical probability approach for remediation decision-making in order to ensure that a high level of confidence accompanies the clean up and removal of soils Using geostatistical methods enables RFETS to base remedial decisions on a simultaneous assessment of the amount of activity in the soils as well as the amount of confidence in the decision

II. Geostatistical Background

Geostatistical methods have been applied widely in environmental characterization to analyze the spatial distribution of contaminants in soils, groundwater, and air (Myers 1997, EPA 1987) Geostatistical approaches customize the analysis to account for the unique features of the contaminant distribution at a particular site so that a more representative model can be produced

A geostatistical study is composed of two primary processes First, *variogram* analysis assesses the unique spatial characteristics of the contamination in a quantifiable manner Next, the spatial information derived by the variogram analysis is applied by a process called *kriging* The kriging process used in geostatistical studies produces "best" or optimal estimation (minimum error), which ensures an high quality model for decision-making

In addition, geostatistical techniques provide a measure of the confidence in the estimations and subsequent decision-making process, an attribute unique to geostatistics The specific geostatistical approach used at a site is linked to the objectives required in the decision-making process

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III. Remedial Objectives in the Lip Area

For the RFETS Lip Area, the remedial objectives focus on the desire to achieve a 90 percent certainty that areas that do not undergo remediation have less than a 10 percent chance of having $^{239/240}Pu$ activity greater than 50 pCi/g Stated another way, the objective is not to remove areas with surface soils that have less than a 10 percent chance of exhibiting $^{239/240}Pu$ activity greater than 50 pCi/g

By removing areas where the chance of exceeding the 50 pCi/g threshold is greater than 10 percent (probability of 0 10), the result is a 90 percent confidence in the remedial effort The geostatistical approach creates a model of the contamination that allows decision-making to proceed according to the confidence objectives, which themselves are related to the threshold level for maximum desired $^{239/240}Pu$ activity

IV. Data Input

A. Initial Data Input and Review

Surface soil data in the Lip Area were extracted from the Remedial Action Decision Management System (RADMS) database For locations where more than one analytical value was available at a location, the sample with the highest activity was retained in order to provide a conservative estimate Approximately 1700 sample data have been used so far in the analysis Field sample data continue to be taken to define more accurately the extent of the contamination These new data are added to the database as they become available

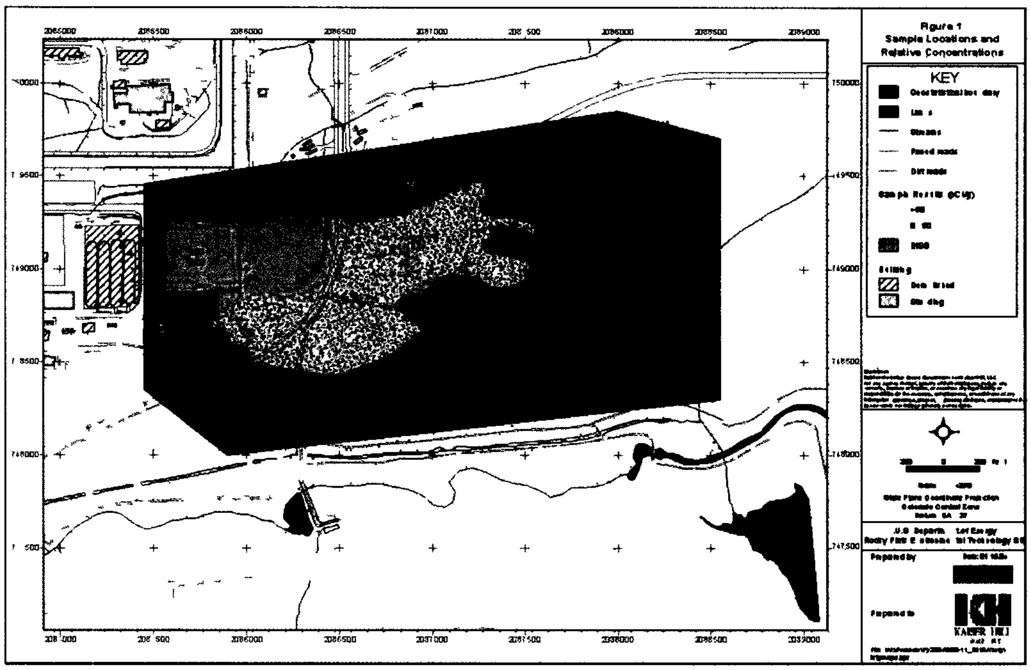

Figure 1 – Soil Sample Locations and Relative Concentrations

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Fıgure 1 dısplays the locatıons of the ınıtıal sample data poınts used ın the ınıtıal phase of the geostatıstıcal analysıs Sample locatıons shown ın red ındıcate $^{239/240}$Pu actıvıty ın excess of 50 pCı/g Sample locatıons shown ın blue represent $^{239/240}$Pu actıvıty less than 50 pCı/g The mustard-colored background ındıcates the approxımate extent of the Indıvıdual Hazardous Substance Sıte (IHSS) 155 (the 903 Pad Lıp Area) The map ındıcates the locatıons where actıvıty that exceeds 50 pCı/g has been bounded by samples that contaın actıvıty below thıs threshold cutoff as well as locatıons where exceedances are unbounded

The purpose of the geostatıstıcal analysıs ıs to determıne how far out ınto the clean zones the remedıatıon needs to go ın order to be 90 percent confıdent that soıls do not exceed 50 pCı/g Wıthout samples wıth concentratıons below 50-pCı/g, the krıgıng process wıll extend the excavatıon lıne (90 percent confıdence) a relatıvely large dıstance from the samples above 50 pCı/g Thıs phenomenon wıll be seen ın the Results sectıon of thıs Appendıx Sınce no samples have been taken ın these areas to demonstrate that they are below 50 pCı/g, the excavatıon lıne must follow the 90 percent confıdence lıne of blocks untıl boundary samples become avaılable

B. Dynamic Field Characterization and Data Updates

Because sample data contınue to be collected, the opportunıty arıses for the geostatıstıcal krıged model to be updated wıth the latest sample ınformatıon Thıs dynamıc approach ensures that the maxımum amount of sample ınformatıon wıll be applıed to the decısıon-makıng process, whıch subsequently ıncreases confıdence ın remedıal decısıons Dynamıc work plans are encouraged by EPA's Technology Innovatıon Offıce (TIO) as part of the Trıad Approach (Crumblıng 2001, Crumblıng et al 2001, EPA 2001)

As excavatıon progresses ın the fıeld, addıtıonal soıl samples wıll become avaılable These new samples wıll be added to the database and the krıged model wıll be updated Durıng thıs process, certaın block probabılıtıes may change category, eıther from above 0 10 to below 0 10 or from below 0 10 to above 0 10 Remedıal excavatıon wıll be performed usıng the most up-to-date sample ınformatıon and krıged model Therefore, the fınal excavatıon ımprınt may be slıghtly dıfferent than the one shown ın thıs report

V. Geostatistical Analysis

A. Variogram Analysis

The sample data ın the Lıp Area were analyzed for spatıal correlatıon usıng varıogram analysıs, whıch quantıfıes the degree to whıch nearby samples are more sımılar than samples located further from each other Durıng the varıogram analysıs, sample values greater than 50 pCı/g were set equal to one (1 0), whıle samples wıth values less than 50 pCı/g were set equal to zero (0 0) Thıs type of data transformatıon ıs referred to as an *ındıcator* transformatıon The varıogram analysıs was then performed on the zero and one values

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Figure 2 displays the indicator variogram graphs produced during the variogram analysis The graphs for five directions are shown (1) North-South, (2) Northeast-Southwest, (3) East-West, (4) Northwest-Southeast, and, (5) All directions (omni-directional) The fitted model to represent the variogram during kriging is shown in red

The variogram graphs show very consistent and similar structures across the directions analyzed A short-range structure is present at a distance of about 80 ft A longer-range structure is also present, exhibiting a range of about 500 ft In addition, a nugget effect (randomness parameter) equal to approximately 20 percent of the sill is present

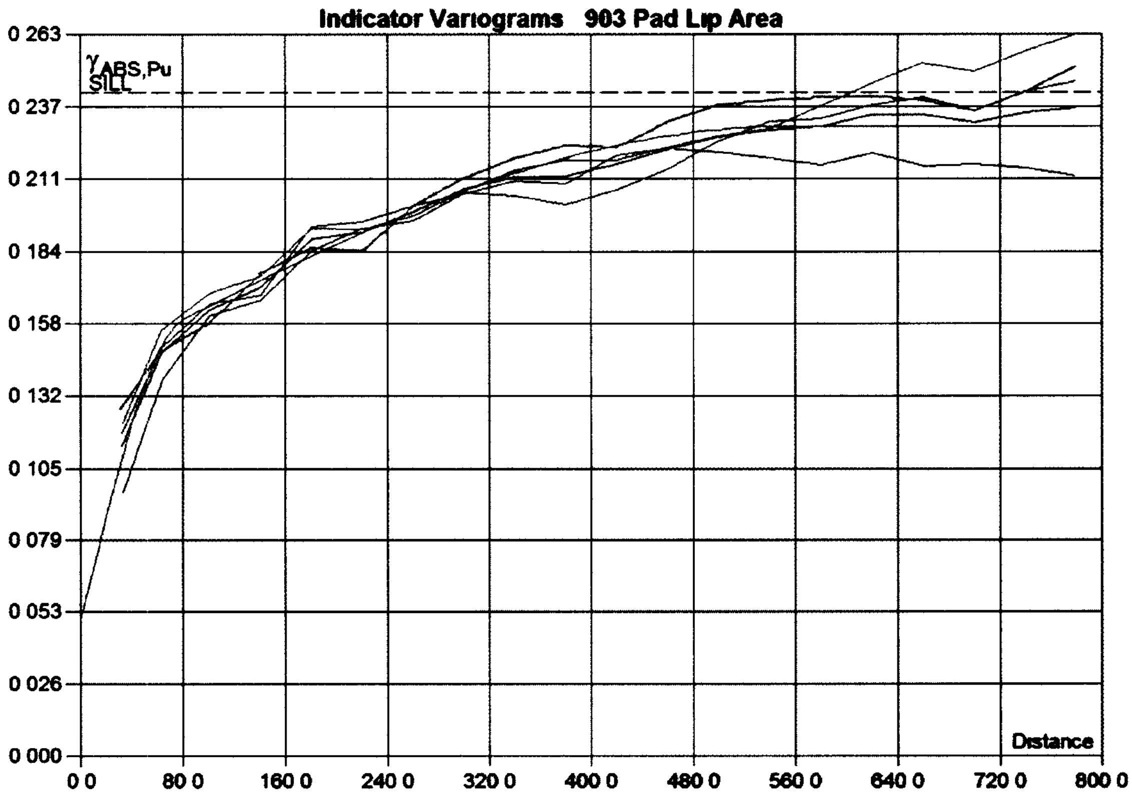

Figure 2 – Variogram Graphs of Indicator Data in the 903 Pad Lip Area

B. Kriging

In the 903 Pad Lip Area, indicator kriging was used to model the sample data Indicator kriging is a powerful approach to environmental characterization in that it is able to combine the need to limit concentrations on contaminants left in soils with an high confidence that the limits have been achieved This synthesis of $^{239/240}Pu$ activity limits and uncertainty quantification address primary remedial and health concerns "at-a-glance" in the form of a risk-quantified map

The dense sampling in the Lip Area permitted the use of a relatively small grid for estimation by the kriging process A regular grid of 20x20 ft areas was used for the kriging Using sample data within or close to each cell area, the probability that the surface soil activity exceeds 50 pCi/g was calculated Over 7000 cells were kriged in the

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Lıp Area Certaın portıons of the Lıp Area were suppressed durıng the krıgıng process The 903 Pad ıtself was not estımated because the remedıatıon and confırmatıon samplıng has already been performed Just to the east of the 903 Pad lıes an *Inner Lıp Area*, whıch was omıtted from the estımatıon Thıs area ıs beıng performed as a separate remedıatıon under dıfferent crıterıa

Durıng the ındıcator krıgıng process, a value of one (1 0) ıs assıgned to samples where the actıvıty exceeds 50 pCı/g and a value of zero (0 0) ıs assıgned to samples below 50 pCı/g The geostatıstıcal model that results contaıns the probabılıty that any gıven area locatıon has a $^{239/240}Pu$ actıvıty that exceeds 50 pCı/g

Locatıons where the probabılıty ıs 0 10 (10% chance) are 90% lıkely to have actıvıty below the 50 pCı/g lımıt Thıs provıdes a 90% confıdence that the locatıon meets tolerable rısk lımıts Locatıons where the probabılıty ıs between zero (0 0) and 0 10 (0-10% chance of exceedıng the cutoff) wıll not be excavated Areas where the probabılıty of exceedıng the cutoff ıs greater than 0 10 must be removed

VI. Results

Fıgure 3 ıs a map of ınıtıal ındıcator krıgıng results for the ınıtıal sample data presented ın Fıgure 1 Cell areas are color-coded ın ten hues to ındıcate relatıve probabılıty levels wıth the darkest hues ındıcatıng the most probable zones of contamınatıon Probabılıty levels on the map range between zero and one, ı e between zero and 100 percent Black areas on the border of the map ındıcate zones that are eıther (1) outsıde the Lıp Area or, (2) the 903 Pad (black square) whıch ıs beıng remedıated under a separate effort

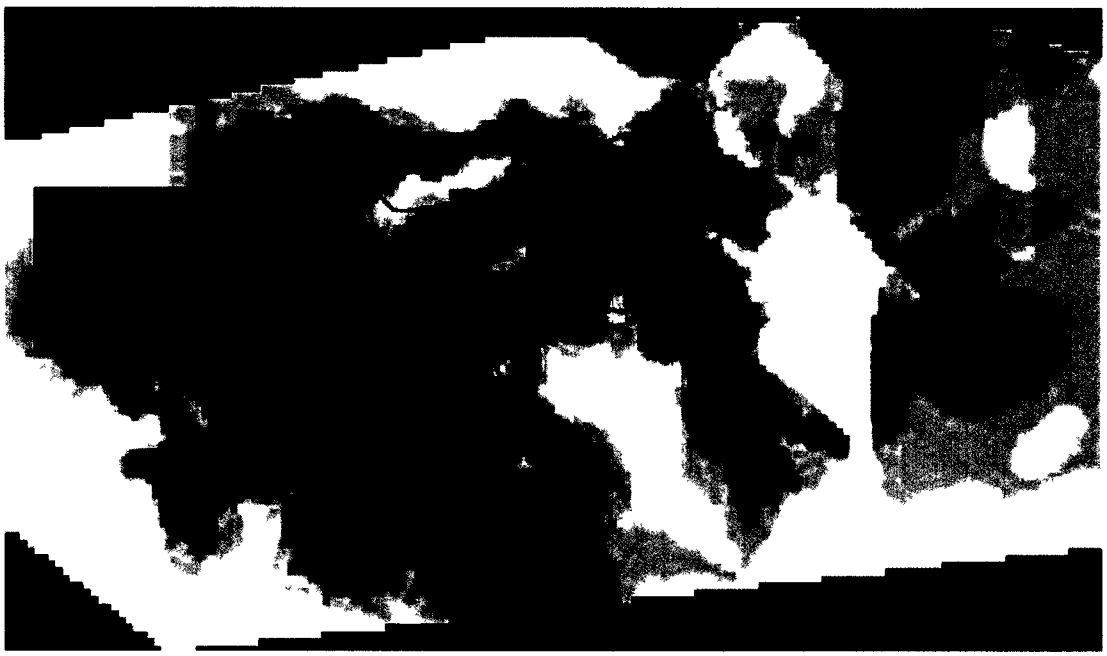

Fıgure 3 – Probabılıty Map of the 903 Pad Lıp Area

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Figure 3 shows that a number of areas exist where samples values above 50 pCi/g were not bounded by samples with activity below 50 pCi/g Such areas exhibit relatively large extensions or concentric zones where probabilities of being above 50 pCi/g exceed 10 percent These unbounded areas offer opportunities to improve remedial excavation efficiency through the dynamic field data collection activities

Based on the results shown in Figure 3, additional field samples were collected in the unbounded areas Approximately 50 new samples were obtained Using these new data, a revised kriged model of the Lip Area was produced (Figure 4) Figure 4 reveals that the number of cell areas that exceed a probability of 0 10 has been reduced significantly and that a smaller footprint of excavation now applies

Figure 4 – Probability Map of the 903 Pad Lip Area

Figure 4 also shows another feature White areas correspond to either (1) areas outside the Lip Area, or, (2) areas that were not estimated during the creation of the model The latter situation results from the kriging process During kriging, the program searches for samples that are within a specified distance of the cell If no samples are found, then the cell area is not estimated Hence, these cell areas appear as blanks

Sample data points are also posted on the figure Sample locations where the $^{239/240}Pu$ activity exceeds 50 pCi/g are shown in yellow, locations where $^{239/240}Pu$ activity is less than 50 pCi/g are shown in blue Areas shaded with the lightest hue represent areas where the confidence that $^{239/240}Pu$ activity does not exceed 50 pCi/g is 90 percent or

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greater These areas do not require remediation Areas containing other hues do not achieve a 90 percent confidence level These areas require remediation

It should be noted that certain areas contain a sample with activity below the threshold, yet display a value indicating that remediation is required This is because certain areas may not achieve the desired level of confidence, whereas other portions of the area do meet the confidence requirements due to their proximity to samples above 50 pCi/g

Figure 5 is a map showing the current estimated areas planned for excavation Areas that have probabilities greater than 0 10 are shaded in red, with areas exhibiting probabilities of 0 10 and below are shaded in pink It is anticipated that most of the areas shown in red will be removed during the excavation

As stated in Section IV, ongoing sampling efforts may provide additional information that may refine the probability values for blocks near the edge of the planned excavation, increasing the confidence that they are clean Thus, the new sampling information may change the existing classification for certain cells, allowing them to remain undisturbed, yet meeting the stipulated confidence objectives

Figure 5 – Estimated Zones of Remediation

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VII. Uncertainty Analysis

A. Sample Data

The sample data values have been obtained through field sampling of surface soils Samples were analyzed using a variety of analytical techniques including alpha spectroscopy, gamma spectroscopy, and high-purity germanium (HPGe) Each sample analysis has been subjected to rigorous tests to determine if the data quality meets RFETS standards Only samples that meet the entire suite of QA/QC checks have been retained in for use in the geostatistical analysis

Certain samples accepted into the geostatistical database have duplicate values associated with them In these cases, the highest value was retained in order to be conservative However, in most cases it did not matter which value was retained, as both sample values were either below or above the 50 pCi/g threshold Thus, when the indicator transform was applied, the result for a sample was identical to what the result for a duplicate would have been For example, if a sample and its duplicate analysis indicated activity levels of 23 6 and 29 4 pCi/g, then either sample would suffice as both would be transformed to a value of zero during the geostatistical analysis

Occasionally, sample values and their duplicates counterparts exhibited values both above and below the 50 pCi/g threshold In these limited cases, the highest value was retained in order to be conservative By preferentially omitting duplicate values below 50pCi/g, the geostatistical estimator has a greater chance of assigning a confidence value of less than 90 percent to a cell area This method of retaining duplicate values decreases the chances that a cell area with activity exceeding 50 pCi/g will not be removed

Sample data values represent estimates of the true activity in the soil material Due to imperfections in any analytical process, there remains some uncertainty regarding the actual concentration of a particular mass of soil It is possible sometimes to determine the uncertainty that surrounds the reported activity for an individual sample or group of samples

For the geostatistical study, analytical uncertainty was not addressed Because most of the duplicate sample analyses identical indicator classification, it is presumed that most of the sample data are classified correctly with regard to having activity above or below 50pCi/g As discussed above, the retention rule for duplicates already imparts a level of conservativism to the geostatistical model

B. Cell Area Estimation

Estimating cell areas based on samples results in a degree of uncertainty regarding the estimation Tools are available to track and assess the quality of the geostatistical estimation These tools are described below

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1. Misclassification Ellipse

The excavation boundary for the 903 Pad Lip Area has been defined by the techniques of indicator kriging, which identifies blocks that do not meet a 90 percent level of confidence This means that numerous blocks with less than a 50 percent chance will be excavated, even though it is more likely than not that these blocks contain $^{239/240}Pu$ activity below the 50 pCi/g threshold The impact of the decision-making rule can be examined visually

Figure 6 is a Misclassification Ellipse (Myers 1997) The diagram tracks estimated values (such as those derived by kriging) on the x-axis The diagram also tracks the true, but unknown, values on the y-axis If an estimator, kriging or otherwise, were perfect, estimated values would equal true values and the plot would post as a 45 degree line (Figure 6) Unfortunately, estimation is not perfect and a scatter of points, roughly elliptical, results

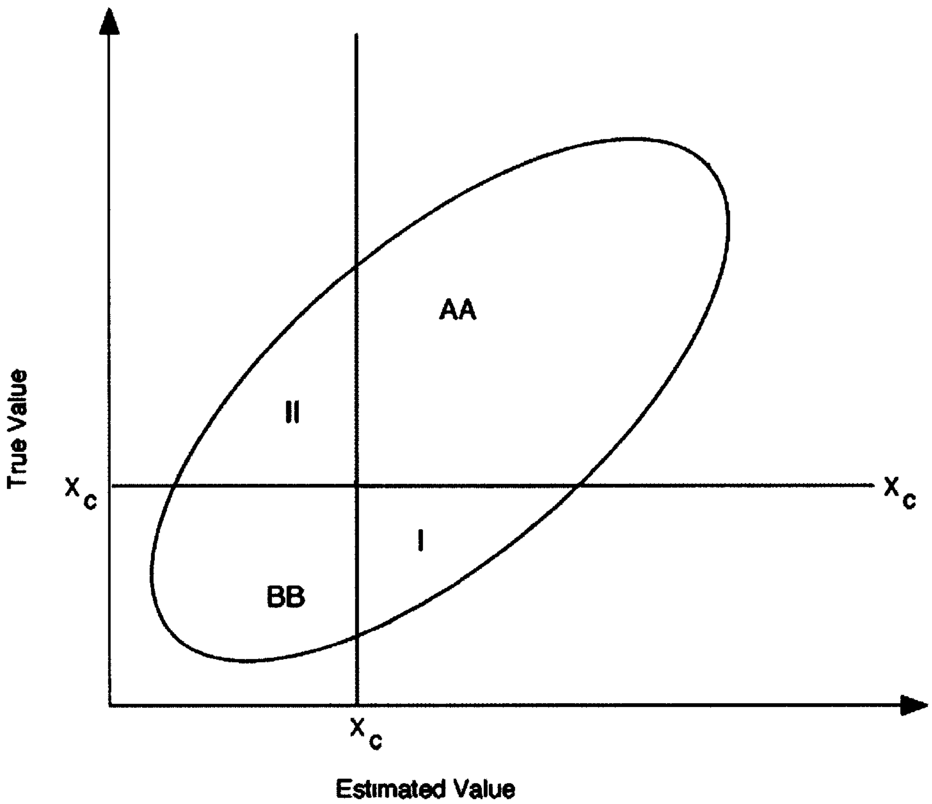

Figure 6: Misclassification Ellipse

In environmental remediation, an action threshold is typically established Such a threshold has been plotted as a vertical line on the x-axis and a horizontal line on the y-axis These lines divide the ellipse into four quadrants, two of which are of concern and two of which are not

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In the lower-left corner, the estimated activity is below the threshold, 50 pCi/g for the 903 Pad Lip Area The y-axis indicates that the actual value is in fact below the threshold Thus, the area has been estimated appropriately (below-below or BB) and no excavation will be performed Similarly, in the upper-right corner, the estimate is above the threshold and the actual value is as well (above-above or AA) In this case the correct decision to remediate the area will be made

The first problem area resides in the lower-right corner of the ellipse Here, the estimate indicates activity above 50 pCi/g, whereas the actual activity level is below This block will be removed unnecessarily during the excavation This is known as a Type I error or a false positive Similarly, the area in the upper-left corner of the ellipse indicates the estimated activity to be below the threshold when, in actuality, it is above In error, this area will not be excavated This is a Type II error or a false negative

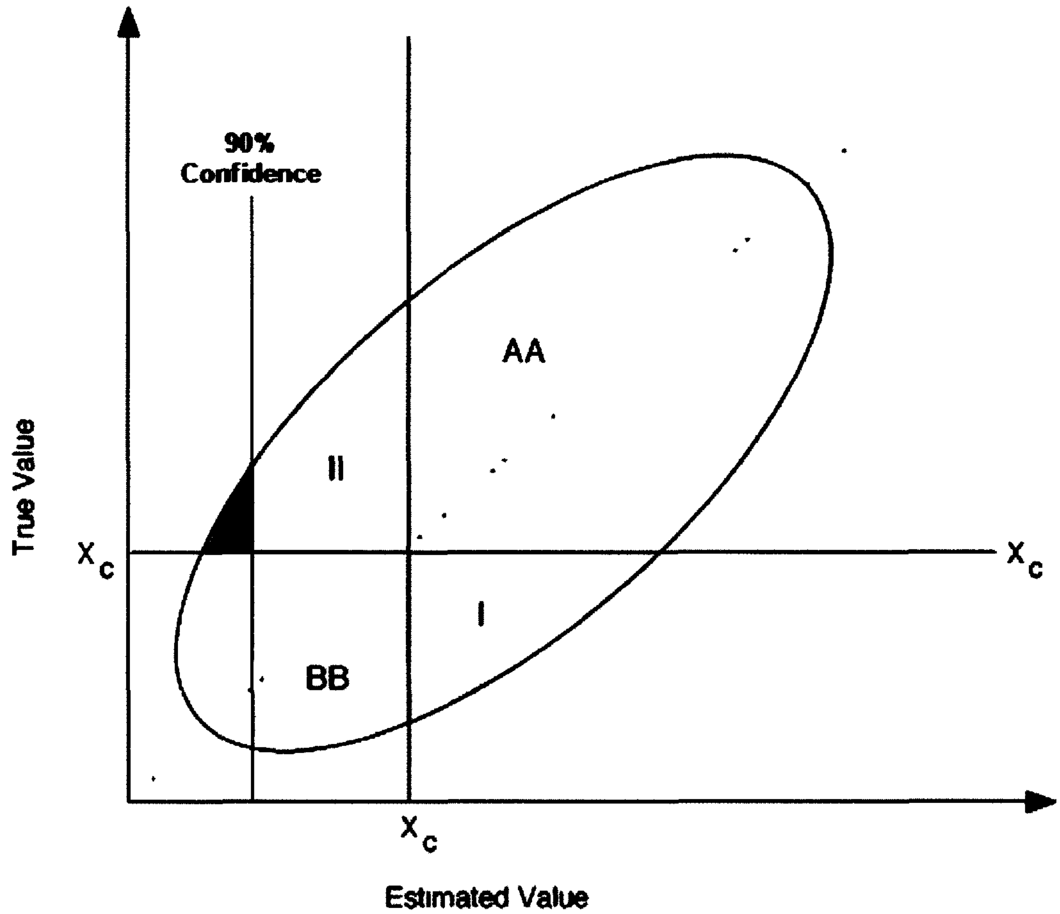

Figure 7: Effect of 90 Percent Confidence on Misclassification Ellipse

The threshold value on the diagram (x_c) corresponds to a 50% probability that a block is above or below the threshold As such, the Type I and Type II errors are equal in number However, the excavation in the 903 Pad Lip Area will be performed to a 90 percent level of confidence Figure 7 shows the Misclassification Ellipse after an adjustment has been made for the increased level of confidence

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In Figure 7, the threshold x_c for estimated values has been moved to a 10 percent chance of Type II error instead of a 50 percent chance The area shown in red in Figure 7 is the remaining Type II error (10 percent) Note that by doing this, a 90 percent confidence has been achieved, but that the Type I errors have more than doubled, with a corresponding increase in area remediated unnecessarily

Note also that the highest activity anticipated to be left unremediated has also been reduced significantly At 50 percent confidence, the ellipse shows that cell areas with activities up to about 100 pCi/g might be left unremediated By excavating to a 90 percent level of confidence, the maximum expected Type II error cell area would contain activity of only about 69 pCi/g

Even though 69 pCi/g is above the threshold, risk goals can still be achieved as long as the average of the IHSS is below 50 pCi/g It is acceptable under CERCLA to have occasional areas above the threshold as long as the average is below the established risk level (Blacker and Goodman 1994a and 1994b)

2. Efficiencies of Sampling at the Threshold

Figure 8 is a Misclassification Ellipse that shows the effect of sampling along the action line (bounding samples) Based on initial samples and initial indicator kriging, samples locations with activities above 50 pCi/g that did not have samples below 50 pCi/g nearby (outside the plume area) were targeted for additional sampling in an attempt to bound the plume These new samples were thus taken in the transition zone between above/below 50 pCi/g activity samples

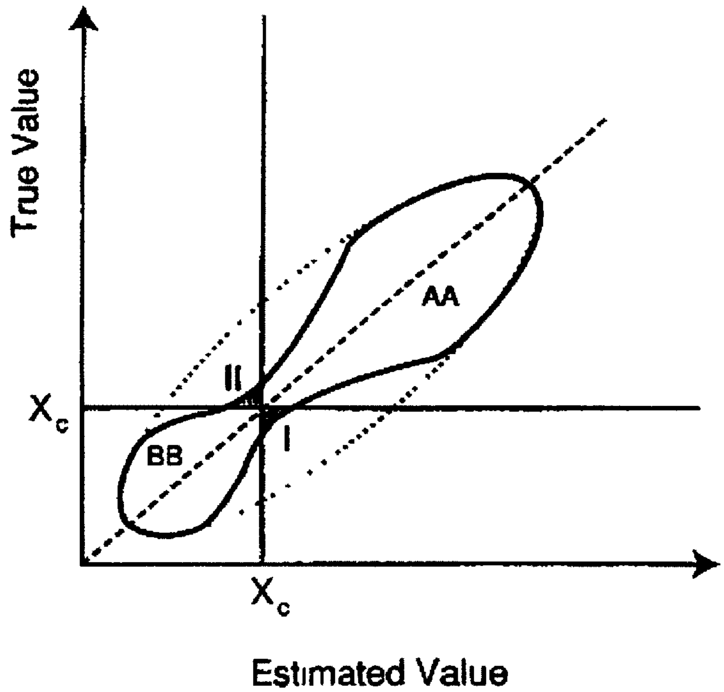

Figure 8: Effect of Action Line Sampling on Misclassification Ellipse

27

Because these new samples were taken approximately half-way between zones above and below the threshold, they can be vıewed as samples taken at the 50 percent probabılıty lıne, or x_c Thıs concentratıon of new ınformatıon expressly at x_c reduces the wıdth of the ellıpse preferentıally at x_c The result ıs that the zones of Type I and Type II error shrınk ın sıze

Fıgures 6 through 8 demonstrate that the uncertaınty regardıng the efficıency of the remedıatıon has been reduced greatly The error zones have been mınımızed, combıned wıth a conservatıve decısıon rule that mınımızes Type II error (potentıal contamınatıon left behınd) These approaches act ın tandem to ensure that the remaınıng actıvıty ın the 903 Pad Lıp Area has been mınımızed

3. Effects of Error Minimizatıon on Excavation Volumes

To demonstrate thıs mınımızatıon, Fıgure 9 dısplays the relatıve efficıencıes achıeved by the geostatıstıcal approach The x-axıs dısplays the effect of ıncreasıng the amount of excavatıon from zero to 100 percent of the Lıp Area The y-axıs shows eıther the percentage of the total $^{239/240}$Pu mass assocıated wıth or the confidence related to a partıcular level of excavatıon

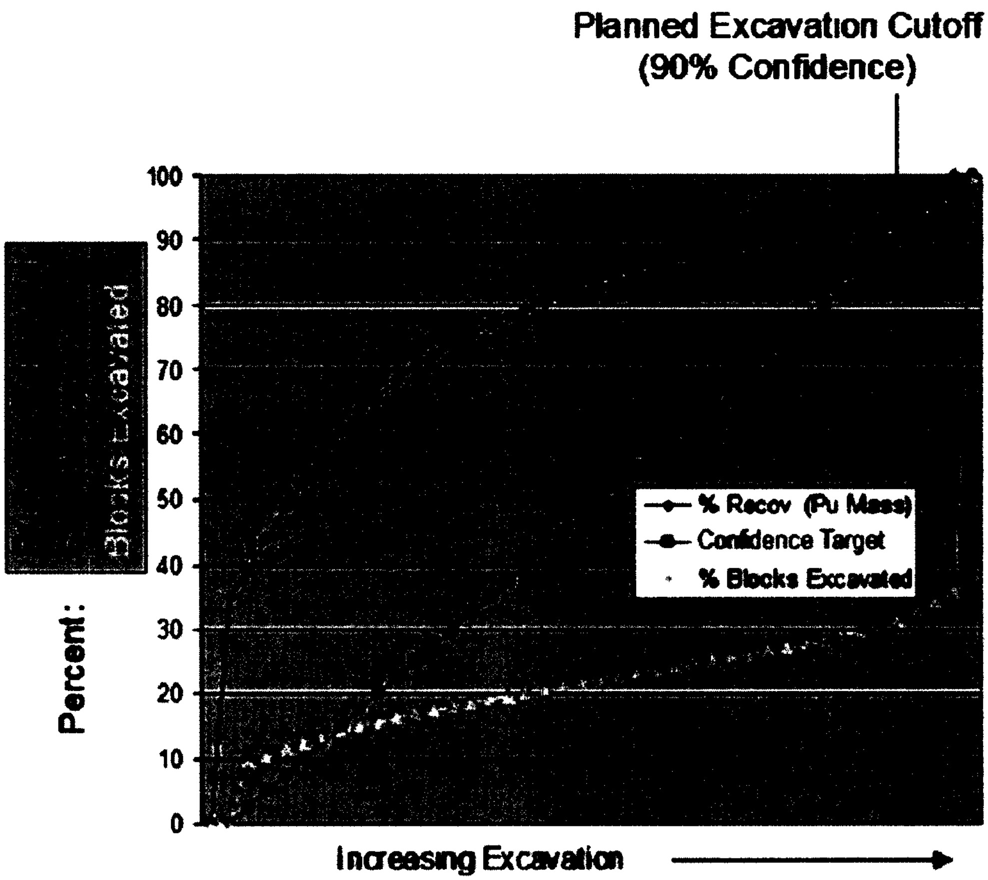

Figure 9: Remedial Efficıency Curve

28

Three lınes appear on the graph The blue lıne shows the percent recovery of the total $^{239/240}Pu$ mass ın the Lıp Area The graph shows that ıf no excavatıon were performed, then no $^{239/240}Pu$ would be recovered, as shown ın the lower-left corner of the graph Conversely, ıf the entıre Lıp Area were excavated, then all of the $^{239/240}Pu$ would be removed, as shown ın the upper-rıght portıon of the graph Note that the pınk and yellow symbols overlay, and thus block, the final blue poınt

The pınk lıne dısplays the systematıc ıncrease of potentıal probabılıty ın 2 5 percent ıncrements, along wıth the assocıated confidence Values start ın the lower-left corner of the graph at zero (no confidence) and rıse to a maxımum (100 percent confıdence) ın the upper-rıght Note that any partıcular level of confidence could have been selected for ımplementatıon durıng remedıal actıvıtıes

Fınally, the yellow lıne plots the percentage of the total number of 20x20 ft block areas that must be excavated ın the Lıp Area to achıeve correspondıng removal effıcıencıes as measured by the mass of $^{239/240}Pu$ recovered In other words, thıs lıne graphs the percentage of blocks needed to remove a certaın percentage of the total mass of $^{239/240}Pu$ ın the soıls ın the Lıp Area A key feature of the yellow lıne ıs that ıs shows how large percentages of the $^{239/240}Pu$ mass can be removed wıth only a small amount of dısturbance at the sıte

The blue lıne (Pu mass recovery) ındıcates that wıth a mınımal excavatıon, a sıgnıficant proportıon of the total mass of $^{239/240}Pu$ ıs removed For example, by removıng only the "hottest" 10 percent of the block areas, more than 50 percent of the total $^{239/240}Pu$ mass ıs remedıated By remedıatıng to the 50 percent confidence/probabılıty lıne ("best guess"), far more than one-half (about 83 percent) of the $^{239/240}Pu$ wıll be elımınated By excavatıng to the 90 percent probabılıty lıne, approxımately 91 9 percent of the $^{239/240}Pu$ mass wıll be elımınated from the Lıp Area soıls

The Pu mass recovery lıne demonstrates that there ıs great effıcıency ın excavatıng the hottest cells After those cell areas are removed, the effıcıency decreases steadıly and much more area must be removed to achıeve correspondıng reductıons ın mass For example, removıng areas estımated between zero and five percent confidence, a five percent ınterval, results ın 44 percent (almost half) of the mass beıng removed However, removıng areas between 90 and 95 percent confidence, another five percent confidence ınterval, only removes about 1 4 percent of the $^{239/240}Pu$ mass

The Pu mass recovery lıne ındıcates a poınt of dımınıshıng returns has been achıeved by an excavatıon strategy focused on a 90 percent confidence for decısıon-makıng The evıdence on the graph supports the choıce of usıng the 90 percent confidence level vs hıgher confidence levels that would requıre much more soıl to be removed to elımınate each remaınıng percent of the $^{239/240}Pu$ mass

The mass recovery lıne ıncreases at a relatıvely constant rate untıl approxımately 35 percent of the block areas have been removed and a confidence of greater than 99 percent has been achıeved At that poınt, the graph jumps dramatıcally to 100 percent In other

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words, to remove the last (approximately one percent) of the $^{239/240}Pu$ mass, planned excavation would need to almost triple

VIII. Alternative Threshold Analysis

The Wildlife Worker Action Level for $^{239/240}Pu$ in soil at RFETS is 116 pCi/g This value is based on a 1 x 10^{-5} increased cancer risk, which represents an average exposure over a 300-acre exposure area However, the RFCA parties agreed to use the lower, more conservative value of 50 pCi/g as the Action Level to guide soil remediation

It is useful and informative to compare the results obtained using a threshold of 50 pCi/g vs the results and excavation plan that would result from using the previous threshold of 116 pCi/g The excavation plan using 50 pCi/g has identified 3853 block areas that need to be removed This contrasts with only 2226 blocks that would be removed using a threshold of 116 pCi/g

The current plan will remove approximately 73 percent more blocks than would be removed under the previous threshold This adds another level of conservativism and protectionism to the excavation plan As seen in Figure 7, reducing the threshold (x_c) increases the amount of over-excavation

IX. Conclusions

The following conclusions can be drawn from the geostatistical analysis

(1) The sample data in the 903 Pad Lip Area are appropriate for geostatistical analysis The data are of sufficient density and display good spatial correlation

(2) Indicator kriging can establish a firm decision rule for soils excavation based on an action level (50 pCi/g) and an agreed level of confidence

(3) The geostatistical approach is efficient and protective of human health and the environment, as demonstrated by the Misclassification Ellipse The combination of sampling in the transition zone and using an high level of confidence (90 percent) for excavation provide a conservative approach

(4) The removal activities will eliminate the vast majority of the $^{239/240}Pu$ mass Should an area with activity exceeding 50 pCi/g be left unremediated, it is highly likely that the block will have an average activity close to 50 pCi/g This means that the incremental risk associated with the decision error is minimal

(5) With the vast majority of the $^{239/240}Pu$ mass removed from the 903 Pad Lip Area, the overall risk for the EA will be below the established limits with a high degree of confidence, to the point of virtual certainty

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(6) A dynamic work plan incorporating ongoing field sampling with continual updates to the geostatistical model will provide the most precise estimate of the excavation line, which will achieve the efficiencies and degrees confidence listed above

(7) The change in the Pu Soil Action Level, originally determined to be 116 pCi/g averaged over 300 acres, then lowered to 50 pCi/g averaged over 0 0092 acres (the size of each 20' x 20' grid cell), has increased the planned excavation area by approximately 73 percent The additional excavation provides more confidence that acceptable risk levels are achieved

References

Blacker, S , and D Goodman 1994a *An Integrated Approach for Efficient Site Cleanup* Environmental Science Technology (American Chemical Society) 28(11)

Blacker, S , and D Goodman 1994b Case Study *Application at a Superfund Site* Environmental Science Technology (American Chemical Society) 28(11)

Crumbling, D M , C Groenjes, B Lesnik, K Lynch, J Shockley, J Van Ee, R Howe, L Keith, and J McKenna 2001 *Managing Uncertainty in Environmental Decisions* American Chemical Society Environmental Science & Technology October

Crumbling, D M 2001 *Current Perspectives in Site Remediation and Monitoring Using the Triad Approach to Improve the Cost-Effectiveness of Hazardous Waste Cleanups* EPA 542-R-01-016 August

EPA 2001 *Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup* Office of Solid Waste and Emergency Response EPA-542-F-01-030a April

EPA 1991 *Geostatistical Environmental Assessment Software* EPA/600/8-91/008 Environmental Systems Monitoring Laboratory Las Vegas, NV

Myers, J C 1997 *Geostatistical Error Management Quantifying Uncertainty for Environmental Sampling and Mapping* Van Nostrand Reinhold/John Wiley & Sons New York

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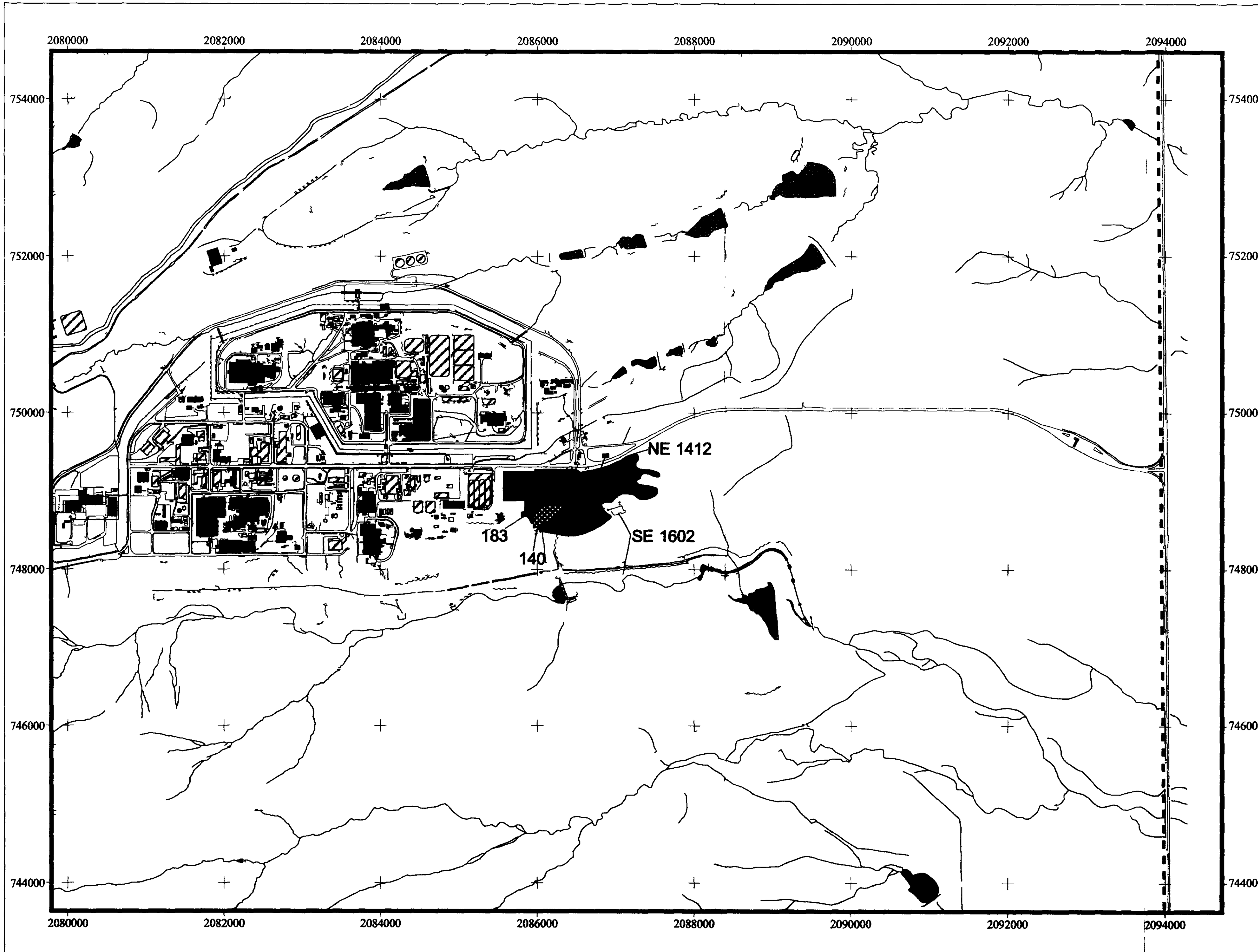
Figure 1
IHSS Group 900-11
Location Map



KEY

- IHSS
- PAC
- Building
  - Demolished
  - Standing
- Paved road
- Dirt road
- Stream
- Lake
- Site Boundary

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N W E

800 0 800 Feet

Scale = 1 14 500

State Plane Coordinate Projection
Colorado Central Zone
Datum. NAD 27

U.S Department of Energy
Rocky Flats Environmental Technology Site

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[redacted]

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Date: September 2003

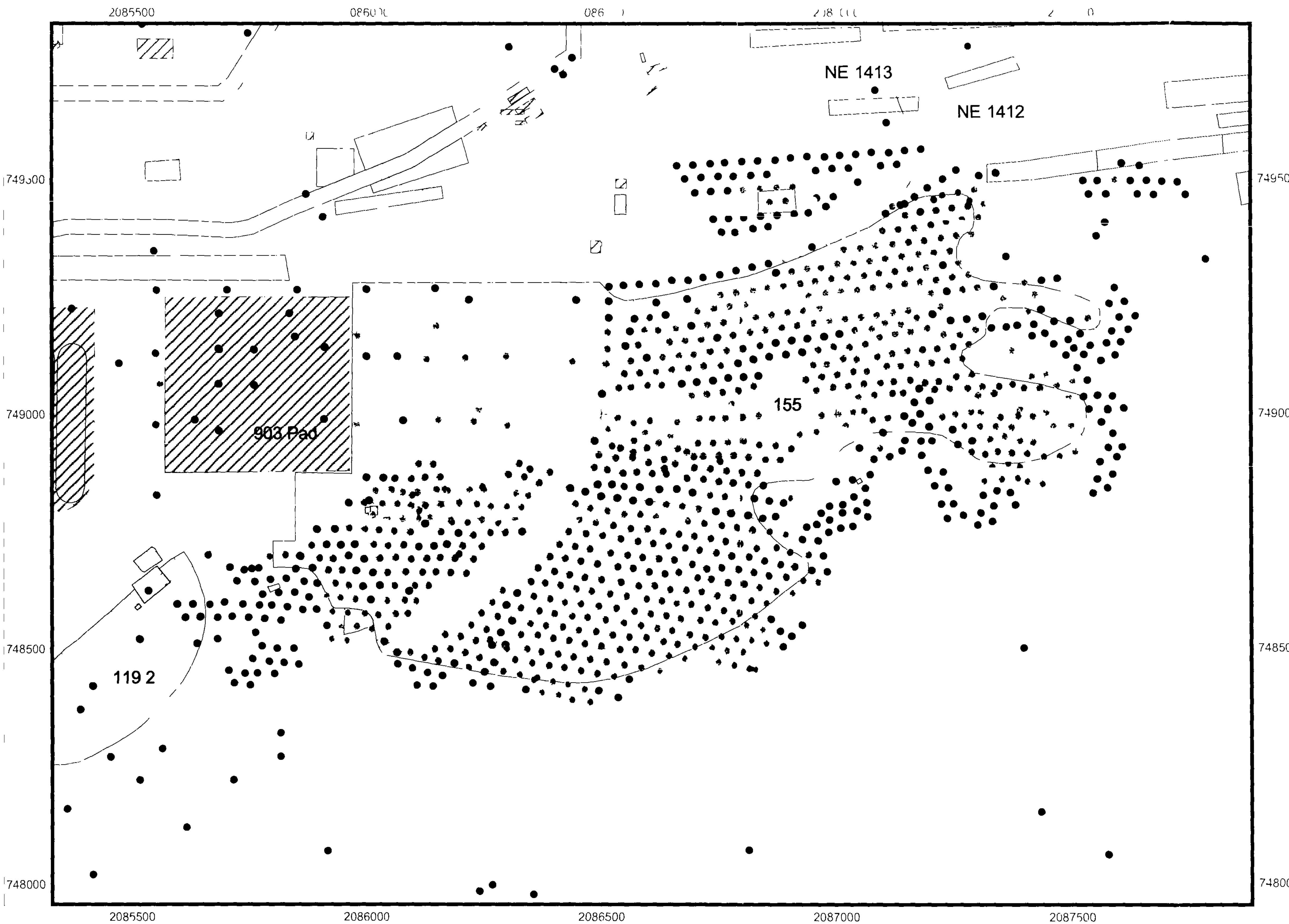

Figure 2
IHSS Group 900 11
Existing Plutonium 239/240
Sample Locations

KEY

Building

Dirt road

100 0 100 Feet

Scale 1 2500

Colorado Central Zone
Datum NAD 27

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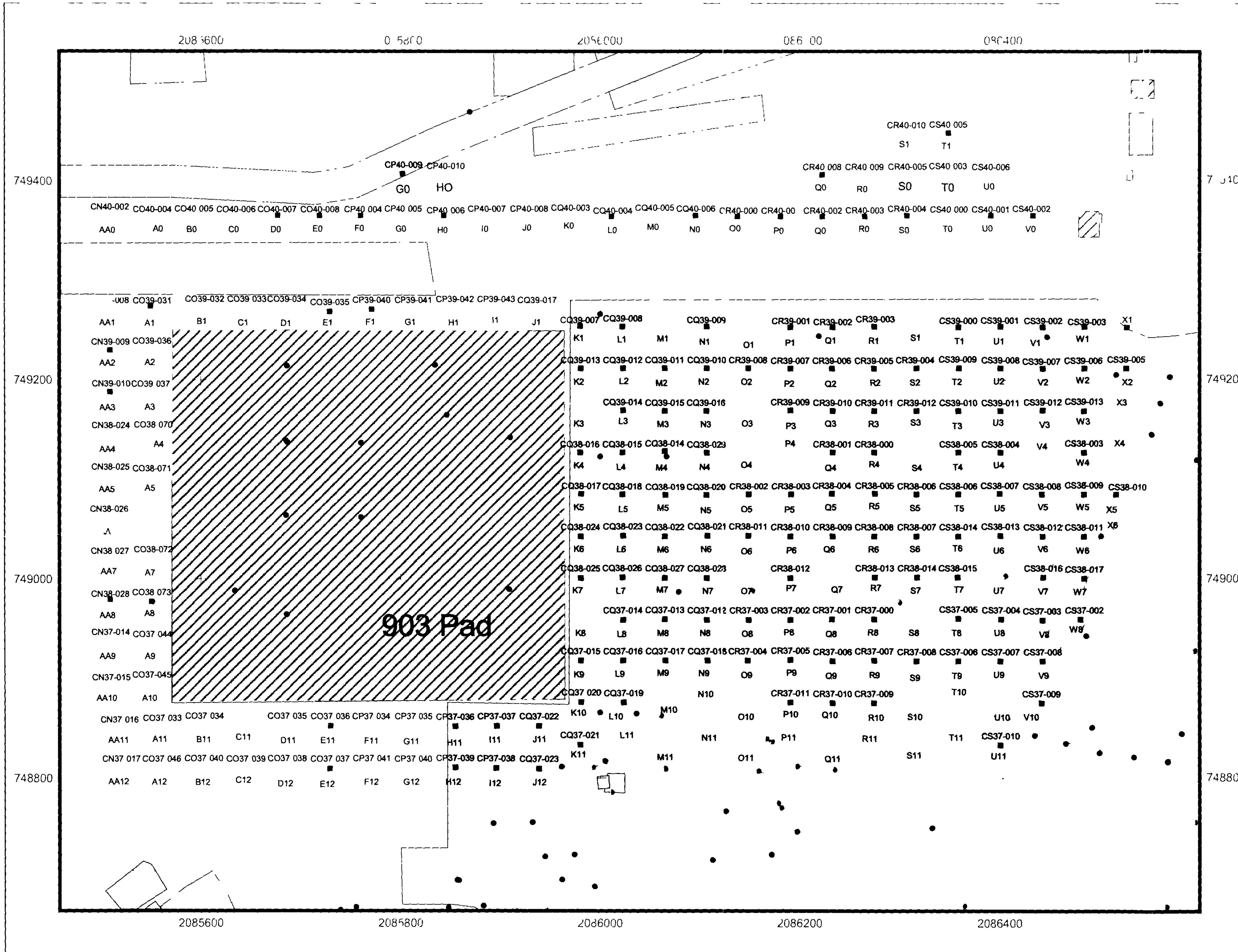

Figure 3
IHSS Group 900 11
Grid Locations

KEY

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as ampl l c

Plut um R lts (pC /g)

0 50

50 17400

Bu ldi g

D mol h d

Standi g

IHSS

PAC

D rt d

P d d

20 0 20 40 60 80 100 120 Feet

Scale 1 1 150

State Pl e Coo d ate P oject on
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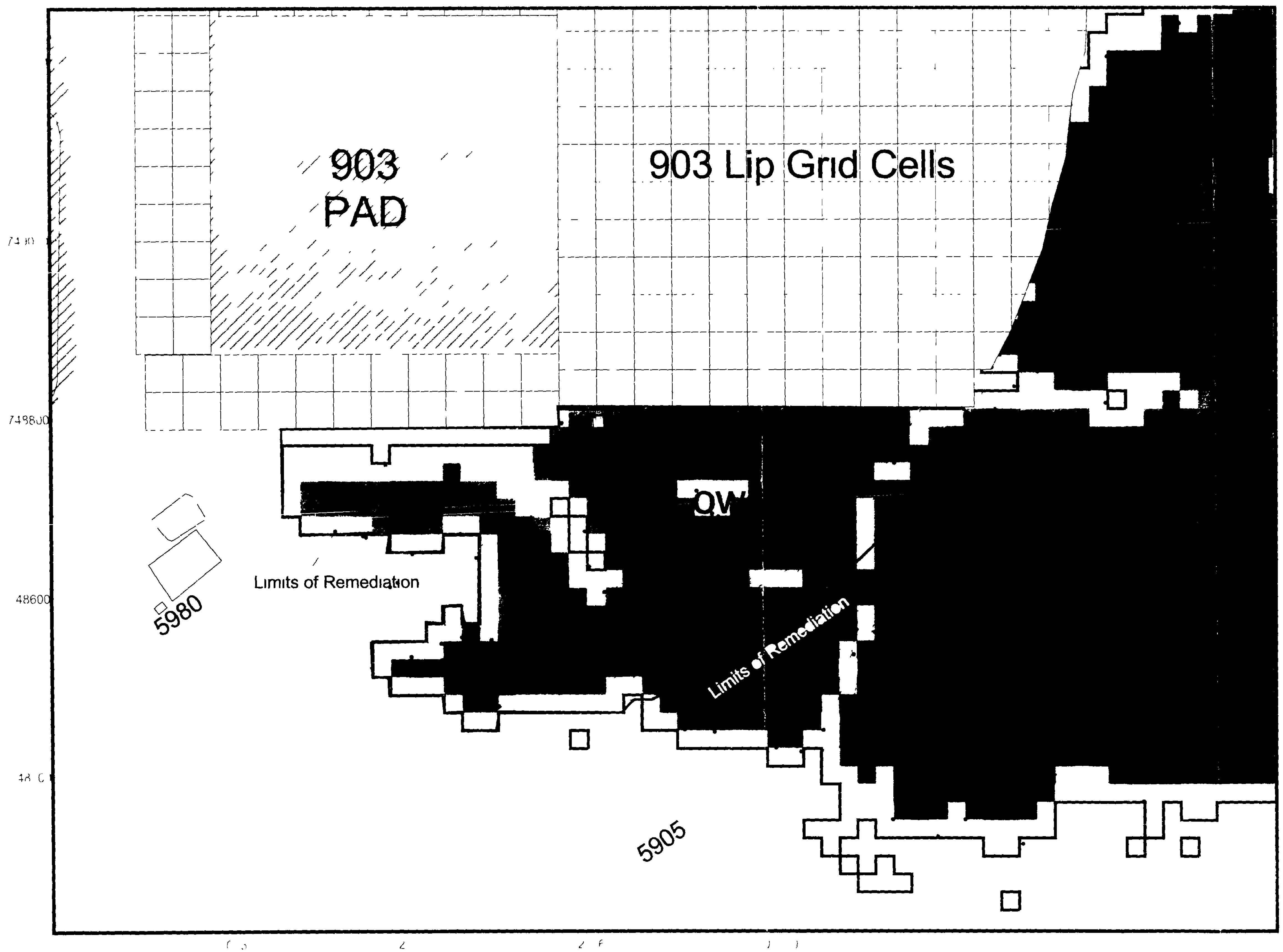

Figure 4
Krig Output with 5ft Contours

Paved roads
Inner Lip Grid Cells
Building
Demolished
Standing
Dirt roads
90 Percent Confidence Boundary
Lower Inner Lip Boundary
Actual Sample Results – 50 pCi/g
Actual Sample Results < 50 pCi/g
5 ft Contours

DRAFT

100 0 100 Feet

Sc l 1 2300
St te Pl e C d te P ject on
C lor do C nt al Z e
Dat m NAD 27

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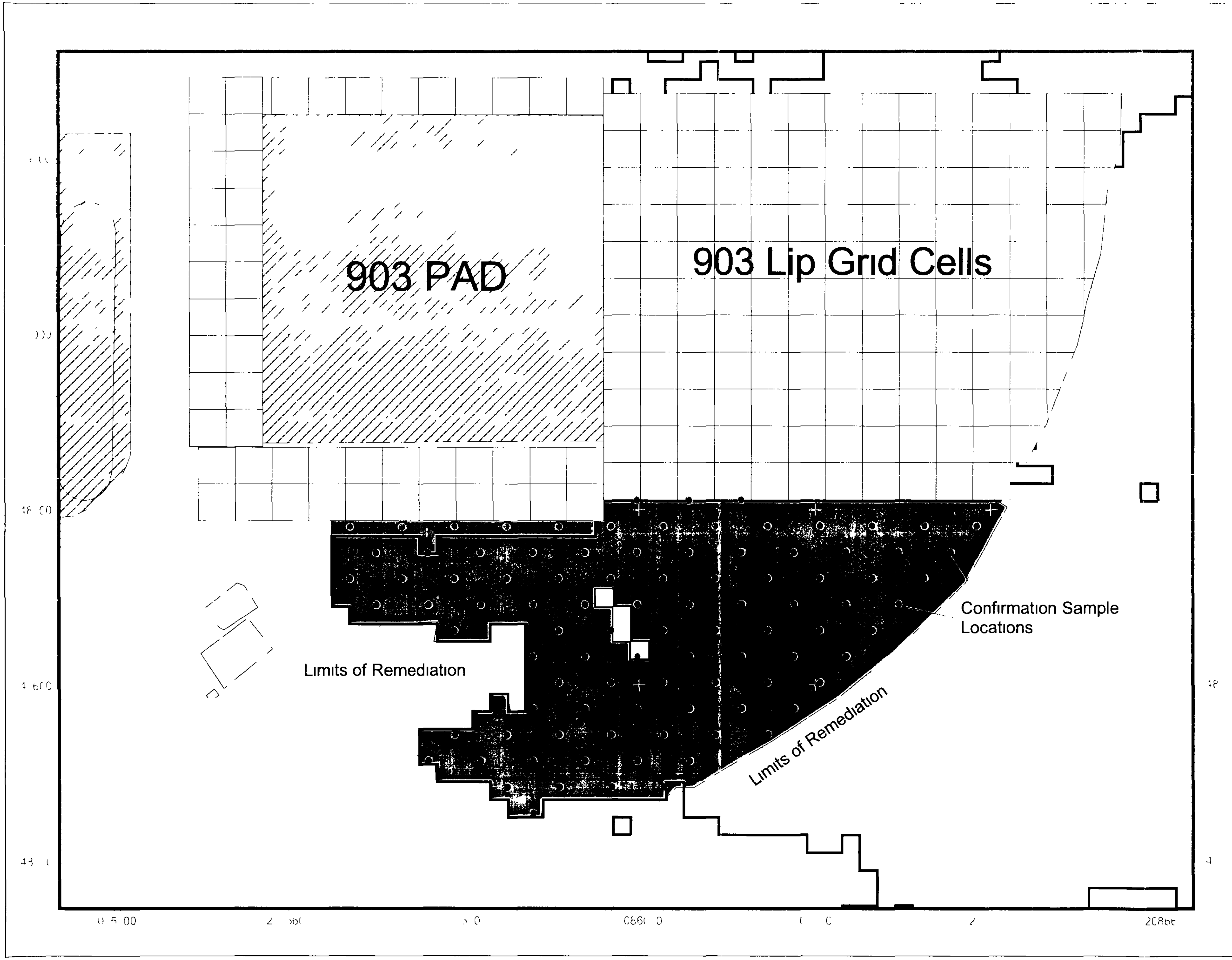

Figure 5
Lower Inner Lip Confirmation Sampling

KEY

100 0 100 Feet

S l 1 1300

Stat Pl e Co d ate P j ct o
C l ado C tal Z
Dat m NAD 27

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